

ENGLISH TRANSLATION DOCUMENT

The following attached document is the English Translation Document for the below referenced Chinese patent application.

Application Date: 2003 08 16

Application Number: 03140199.6

Application Type: Invention

Title: A Type of Improved Graphite and Its Method of Fabrication

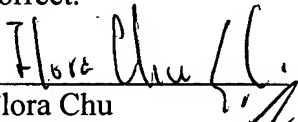
Applicant: BYD LTD.

Inventors: Caisong Zou, Chuanfu Wang, and Junqing Dong

Attorney Docket: BYD-US2003-006

Translation Certification

I hereby certify that the following translation of the respective certified copy is correct.


Flora Chu
Law Offices of Emil Chang
874 Jasmine Drive
Sunnyvale, CA 94086
(408) 733-0008

CERTIFICATION

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Title: A Type of Improved Graphite and Its Method of Fabrication

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People's Republic of China

Commissioner of the State Intellectual

Property Office (signed) Wang Jingchuan

January 5, 2004

Title

A Type of Improved Graphite and Its Method of Fabrication

Abstract of Invention

- 5 A type of improved graphite, including a core material of graphite granules with the surface of said graphite granules coated with a membrane of amorphous carbon where the crystallite interlayer spacing of the core material of graphite granules, d_{002} , is between 0.335nm and 0.340nm. The specific surface area of said improved graphite is between $1.3 \text{ m}^2/\text{g}$ and $4.2 \text{ m}^2/\text{g}$. Its average granule diameter is $8\mu\text{m}$ and $35\mu\text{m}$.
- 10 The fabrication method of said improved graphite is: Immerse said core material of graphite granules in polymer surface modifying solution and stir, separate, sift, then solidify and carbonize. This improved graphite of this invention have excellent high current characteristics, higher reversible specific capacity, longer cycle life, and can satisfy the demands of practical application. The fabrication method of this invention
- 15 has simple technology and low cost, and is easy for industrial production.

Claims

5

1. A type of improved graphite. Its characteristics are: said improved graphite includes a core material of graphite granules and the surface of said graphite granules is coated with a membrane of amorphous carbon. The crystallite interlayer spacing of the core material of graphite granules, d_{002} , is between 0.335nm and 340nm. The specific surface area of said improved graphite is between 1.3 m²/g and 4.2 m²/g. Its average granule diameter is 8μm and 35μm.

2. Said improved graphite of Claim 1. Its characteristics are: the crystallite interlayer spacing of said improved graphite, d_{002} , is between 0.335nm and 0.338nm. The specific surface area is between 1.8m²/g and 3.5m²/g and the average granule diameter is between 10μm and 20μm.

3. Said improved graphite of Claim 1. Its characteristics are: the thickness of said amorphous carbon membrane is between 0.05μm and 1μm.

4. A method for the fabrication of said improved graphite of Claim 1 or 2 or 3, including the following steps:

20 (1) Dissolve polymer surface modifying agent solute in corresponding solvent to obtain polymer surface modifying solution that is almost saturated;

(2) Immerse core material of graphite granules in said polymer surface modifying solution at the ratio of 1.5 liters to 3liters of polymer surface modifying solution to every 1kg of graphite; Stir at 100rpm to 2000rpm for 0.5 hours to 10 hours such that the surface modifying agent is fully touching and adhered to the graphite core material.

(3) Separate core material of graphite granules from polymer surface modifying solution. Heat to dry the remaining solvent on core material of graphite granules. Sift.

(4) Solidify and carbonize the dried graphite in an inert environment to obtain the improved graphite that has its surface modified.

The core material of graphite granules can be natural or man-made graphite. The average graphite diameter is between 7 μ m and 35 μ m.

The polymer surface modifying agent can be one or more of the following: coal pitch, coal tar, petroleum pitch, petroleum coke, benzene, naphthalene, copolymers of benzene and naphthalene copolymer, petroleum wax, petroleum resin.

The organic solvent can be one of the following: acetone, anhydrous ethanol, N- methyl pyrrolidone, chloroform, tetrahydrofuran, carbon tetrachloride, and cyclohexane.

Solidification proceeds at 200°C to 600°C. The rate of increase in temperature is 0.5°C/min to 35°C/min. The temperature is held for 0.2 hours to 12 hours.

Carbonization proceeds at 750°C to 1300°C. The rate of increase in

temperature is 0.1°C/min to 30°C/min. The temperature is held for 1 hour to 24 hours.

5 5. Said method for the fabrication of said improved graphite of Claim 4, its characteristic is: said solidification proceeds at 300 °C to 500°C. The temperature is held for 0.5 hours to 3 hours.

6. Said method for the fabrication of said improved graphite of Claim 4, its characteristic is: in said solidification process, the rate of increase in temperature is 5°C/min to 20°C/min.

10 7. Said method for the fabrication of said improved graphite of Claim 4, its characteristic is: said carbonization proceeds at 800°C to 1200°C. The temperature is held for 2 hours to 10 hours.

8. Said method for the fabrication of said improved graphite of Claim 4, its characteristic is: the rate of increase in temperature for said carbonization is 3°C/min to 20°C/min.

15 9. Said method for the fabrication of said improved graphite of Claim 4, its characteristic is: in said step (4) of carbonization process, the rate of decrease in temperature is 5 °C/min to 15°C/min.

Title

A Type of Improved Graphite and its Method of Fabrication

Field of Invention

This invention relates to a type of improved graphite and its method of
5 fabrication. More particularly, it relates to type of improved graphite with excellent
high current characteristics and its method of fabrication.

Background

With the rapid development of the electronic and information technology
10 industries, market demands for power sources of electronic products have increased.
During the last decade, lithium ion rechargeable batteries have seen rapid development
and widespread use as a result of their excellent overall properties.

Since electronic products, especially portable electronic products, are gradually
becoming more complex and miniaturized, the demand for power sources of these
15 products is also increasing. These power sources now require sufficiently high volume
energy density, excellent high current characteristics, and suitable cycle life and reliable
safety properties. Among these, the demand for power sources with dense energy
capacity per body mass and high current characteristics is especially high.

In certain circumstances, electrical products such as modern portable products,
20 electrical tools, electric bicycles, and electric cars have very high demand for electrical
consumption per unit time. Examples include: modern color picture cell phones with

functions such as wireless internet connections and multimedia capabilities, notebook computers demanding the ability to use electricity for a long time, and, the starting mechanism for automobiles. For the lithium ion rechargeable batteries that are being used as the power sources, these products have processes that require the use of high
5 currents. In other words, for many circumstances in recent years, greater demands are made on the high current characteristics of the lithium ion rechargeable batteries.

The high current characteristics of lithium ion rechargeable batteries mainly depend on the material for their positive and negative electrodes. Among these, the active material for the negative electrode is especially relevant in improving the high
10 current characteristics that are mainly dependent on the electrical conducting properties and the stability of the structure of the underlying active material.

At present, the most common active material for the negative electrode in a lithium ion rechargeable battery is a graphite type material as graphite has a lower discharging electricity platform and better cycle stability characteristics. Among these graphite
15 type materials, natural graphite with a higher degree of graphitization has higher specific capacity. However, in the process of attaching and detaching lithium, the structure of the crystallite in the natural graphite can easily be loosened or even destroyed resulting in the deterioration of the cycle and high current characteristics.

Patent CN1230159, Graphite Granules and Using Graphite Granules as the
20 Negative Electrode for Lithium Rechargeable Batteries, invents a type of graphite granules. Lithium rechargeable batteries using those graphite granules have excellent

rapid charge and discharge and cycle characteristics. The characteristics of this type of graphite granules are: lower directional property of the graphite granule resulting from the grouping or joining of many flat shaped granules together such that the directional position of the crystal surface of the neighboring flat shaped crystal granules are not parallel. The rate of attaching and detaching of the Li^+ ion can then proceed more fully at a higher rate thereby obtaining a lithium rechargeable battery made from graphite with excellent high current characteristics. However, this method for fabricating graphite is actually is a type of man-made graphite treatment process that needs temperatures as high as 2800°C for the graphitization treatment resulting in high costs, difficult technology, and difficult to implement for industrial production.

Description of Invention

The object of this invention is to provide a type of improved graphite that has excellent high current characteristics, higher reversible specific capacity, and longer cycle life.

Another object of this invention is to provide a method for fabricating said graphite with simple technology, of low cost and easy to industrialize for production.

This invention for improved graphite is realized through the following plan:

A type of improved graphite, including a core material of graphite granules and the surface of the graphite granules is coated with a membrane of amorphous carbon.

The crystallite interlayer spacing of the core material of said graphite granules, d_{002} , is

between 0.335nm and 0.340nm. The specific surface area of said improved graphite is between 1.3m²/g and 4.2m²/g. Its average granule diameter is between 8μm and 35μm.

Above described technology plan can be further improved by:

- 5 The crystallite interlayer spacing of said improved graphite, d₀₀₂, is between 0.335nm and 0.338nm. The specific surface area is between 1.8m²/g and 3.5m²/g and the average granule diameter is between 10μm and 20μm.

The thickness of said amorphous carbon membrane is between 0.05μm and 1μm.

- 10 The fabrication of said improved graphite of this invention is realized through the following technology plan:

(1) Dissolve polymer surface modifying agent solute in corresponding solvent to obtain polymer surface modifying solution that is almost saturated;

- (2) Immerse core material of graphite granules in said polymer surface
15 modifying solution at the ratio of 1.5 liters to 3 liters of polymer surface modifying solution to every 1kg of graphite; Stir at 100rpm to 2000 rpm for 0.5 hours to 10 hours such that the surface modifying agent is fully touching and adhered to the graphite core material.

- (3) Separate core material of graphite granules from polymer surface
20 modifying solution. Heat to dry the remaining solvent on core material of graphite granules. Sift.

(4) Solidify and carbonize the dried graphite in an inert environment to obtain said improved graphite with surface modification.

The core material of graphite granules can be natural or man-made graphite.

The average graphite diameter is between 7 μ m and 35 μ m.

5 The polymer surface modifying agent can be one or more of the following: coal pitch, coal tar, petroleum pitch, petroleum coke, benzene, naphthalene, copolymers of benzene and naphthalene copolymer, petroleum wax, petroleum resin.

The organic solvent can be one of the following: acetone, anhydrous ethanol, N-methyl pyrrolidone, chloroform, tetrahydrofuran, carbon tetrachloride, and
10 cyclohexane.

Solidification proceeds at 200°C to 600°C. The rate of increase in temperature is 0.5°C/min to 35°C/min. The temperature is held for 0.2 hours to 12 hours.

Carbonization proceeds at 750°C to 1300°C. The rate of increase in temperature is 0.1°C/min to 30°C/min. The temperature is held for 1 to 24 hours.

15 Said technology plan can be further improved by:

Said solidification proceeds at 300 °C to 500°C. The temperature is held for 0.5 hours to 3 hours.

In said solidification process, the rate of increase in temperature is 5°C/min to 20°C/min.

20 Said carbonization proceeds at 800°C to 1200°C. The temperature is held for 2 to 10 hours.

The rate of increase in temperature for said carbonization is 3°C/min to 20°C/min.

In said step (4) of carbonization process, the rate of decrease in temperature is 5 °C/min to 15°C/min.

- 5 The advantages of said improved graphite of this invention are: said improved graphite has excellent high current characteristics, higher reversible specific capacity, and, longer cycle life.

The advantages of said method for fabrication of said improved graphite of this invention is: simple technology, low cost, and easy for industrial production.

- 10 The following embodiments further describe this invention.

Descriptions of Attached Figures

Figure 1 is the scanning electron micrograph of the untreated graphite material used in Embodiment 1.

- 15 Figure 2 is the scanning electron micrograph of the improved graphite made by of Embodiment 1.

Figure 3 is the DSC (Differential Scanning Calorimetry and Thermal Gravimetric analysis) figure of the improved graphite made by Embodiment 1.

- 20 Method of Implementation

This invention provides a type of improved graphite, including the core material

of the graphite granules and its surface coating, the amorphous carbon membrane wherein, the crystallite interlayer spacing, d_{002} , is 0.355nm to 0.340nm. Its specific surface area is $1.3\text{m}^2/\text{g}$ to $4.2\text{m}^2/\text{g}$, and its average granule diameter is $8\mu\text{m}$ to $30\mu\text{m}$.

The average granule diameter is the D_{50} measured by using a particle size analyzer. The
5 crystallite interlayer spacing, d_{002} , is measured using an X-ray diffractometer. The specific area of the surface is obtained using the single-point BET method.

The amorphous carbon membrane that coats the surface of the core material of graphite granules can improve the surface morphology of the granule, lowering its specific surface area, raising the compatibility between the graphite and the electrical
10 conducting solution, and resulting in the improvement of the initial charge and discharge efficiency. It can also compensate for the weakness of the boundary edges of the crystallite structure of the core material of graphite granules, lower the directional characteristics of the crystallite, stabilize the graphite crystallite, and further improve its electrical conduction and the uniformity of the electron distribution. This
15 results in raising the electrical mobility rate electrical migration rate of the Li^+ s and increases the stability of the structure of the negative electrode during the process of charging and discharging resulting in improving the high current characteristics.

In this invention, the average granule diameter of the improved graphite is $8\mu\text{m}$ and $30\mu\text{m}$. The preferred specification is between $10\mu\text{m}$ and $20\mu\text{m}$. If the average
20 granule diameter of the graphite granules is too small, then the graphite granules are too small and the specific surface area is too large. This can damage the reversibility

discharge capacity. If the average granule diameter is too large, then the distance between the graphite granule edge and the center is so large that the Li^+ cannot fully attach and detach making the graphite granules not suitable as the active material for negative electrode of the lithium ion rechargeable battery.

5 In this invention, the crystallite interlayer spacing of the improved graphite, d_{002} , is, between 0.335nm and 0.340nm. The preferred size is between 0.335nm and 0.338nm. The d_{002} of the graphite is mainly determined by the source – natural graphite or man-made graphite with a higher degree of graphitization. The surface modifying process does not greatly affect the d_{002} . Usually, the nearer the d_{002} is to the
10 ideal graphite value of 0.3354nm, the higher the degree of graphitization. The higher the degree of graphitization, the higher is its reversible specific capacity. Therefore, in order to assure the discharge capacity of the lithium ion rechargeable battery, natural or man-made graphite with a high degree of graphitization should be used as the material.

In this invention, the specific surface area of the improved graphite is between 1.3 m^2/g
15 and 4.2 m^2/g . A preferred specification is between 1.8 m^2/g and 3.5 m^2/g . The improved graphite that has undergone the surface modifying treatment effectively lowers the specific surface area of the original graphite material. (The specific surface area of the original graphite material is approximately 5 m^2/g .) The size of the specific surface area directly affects the amount of the irreversible capacity used by the
20 SEI membrane that is formed during the initial charging process. This directly affects the initial charge and discharge efficiency of the battery and the size of the reversible

specific capacity. Therefore, in order to assure the highest reversible specific capacity of the material for the negative electrode, it is better to have as small a specific surface area as possible.

The thickness of the membrane of said amorphous carbon is between and
5 0.05 μ m and 1 μ m. The thickness of the membrane of said amorphous carbon is calculated according to the volume of coating of the surface modifying agent on the surface of the graphite core material granules and the average diameter of the core material of graphite granules, the DSC (Differential Scanning Calorimetry and Thermal Gravimetric analysis) graph of the improved graphite can be obtained by heat analysis.

10 In this invention, the improved graphite is obtained by treating and modifying the surface of the natural or man-made graphite with higher graphitization levels. The fabrication method include the following steps:

Prepare a predetermined concentration of polymer surface modifying organic solution, usually at saturation or almost saturated.

15 Immerse the core material of graphite granules in the polymer surface treatment agent organic solution and stir at a speed of 100rpm to 2000 rpm for 0.5 hours to 10 hours. Then separate the graphite granules by filtering or centrifuge. Heat dry the solvent that is mixed in with the resulting graphite. Sift.

Lastly, solidify and also carbonize the dried graphite in an inert environment.

20 A crushing process is not needed to obtain the improved graphite of this invention.

In the fabrication method of this improved graphite of this invention, said

surface modifying agent is a type of organic matter with a high carbon content. It can be one or more of the following: coal pitch, coal tar, petroleum pitch, petroleum coke, benzene, naphthalene, copolymers of benzene and naphthalene, petroleum wax, and petroleum resin. The corresponding organic solvent can be one of the following:

5 acetone, anhydrous ethanol, N- methyl pyrrolidone, chloroform, tetrahydrofuran, carbon tetrachloride, and cyclohexane.

In the fabrication method of said improved graphite of said invention, the effect of the surface modification is related to the stirring time in above described stirring process. If the stirring time is too long, the thickness of the organic membrane that is

10 adhering to the surface of the core material of graphite granules is too thick and will affect the properties of the improved graphite such as lowering the initial charge/discharge efficiency of the improved graphite etc. If the stirring time is too short, then the membrane of organic material membrane adhering to the graphite core material granule surface is too thin and not uniformly distributed on the surface of the

15 core material of graphite granules thus affecting the properties of the improved graphite.

In the solidification process of the fabrication method of the improved graphite of this invention, increase the temperature at the rate of $0.5^{\circ}\text{C}/\text{min} \sim 35^{\circ}\text{C}/\text{min}$ to reach the desired temperature for solidification. A better range is $5^{\circ}\text{C}/\text{min}$ to $20^{\circ}\text{C}/\text{min}$.

20 The solidification temperature is 200°C to 600°C . A better range is 300°C to 500°C . Hold the temperature for 0.2 hours to 12 hours. A better time is 0.5 hours to 3 hours.

After solidification, increase the temperature at a rate of 0.1 °C/min to 30°C/min to reach the desired temperature for carbonization. A better rate of increase is 3°C/min to 20°C/min. The carbonization temperature is 750°C to 1300°C. A better range is 800°C to 1200°C. Hold the temperature for 1 hour to 24 hours. A better time is 2
5 hours to 10 hours. After carbonization, lower the temperature at the rate of 1°C/min to 20°C/min. A better decrease rate is 5°C/min to 15°C/min. The temperature can also be lowered naturally.

If the carbonization temperature is too low, such as lower than 750°C, then the carbonization of the organic layer on the surface of the core material of graphite
10 granule is insufficient to form a stable compact carbon membrane and minute pores may even be formed. A structure with minute holes and larger specific surface area may even be formed. This is not advantageous in improving the surface morphology holes may even be formed. If the carbonization temperature is too high, such as higher than the 1200°C, there is no apparent improvement in the results. However,
15 the energy usage is increased making this process uneconomical. The time for holding the temperature should not be too short or the carbonization will be insufficient to form a stable carbon membrane. If the temperature is held too long, then energy usage is increased and the process becomes uneconomical.

In the fabrication method of the improved graphite of said invention, furnaces
20 such as: box-style electrical resistance furnace, tubular furnace, push pull tunnel furnace, or rotating tunnel furnace can be used for solidification and carbonization. The

only requirement is that the furnace has to be able to reach desired temperature and can be sealed and be able to aerate the inert environment. Said inert environment can be a mixture of one or more of the following: argon gas, helium gas, and nitrogen gas.

In order to examine the fabrication method of the improved graphite of this invention and the electrochemical properties of the improved graphite fabricated from said method, binder and de-ionized water is added to said improved graphite of this invention. The resultant mixture is stirred, coated and heat dry to make the negative electrode plate of a lithium ion rechargeable battery. Use existing technology with the negative electrode slice made as described above, a positive electrode made with LiCoO_2 , corresponding conducting agent, and binder agent, and corresponding electrolyte solution to make a lithium ion rechargeable battery to test related properties.

[Embodiment 1]

Weigh and dissolve 8g of petroleum coke and dissolve in carbon tetrachloride to formulate 200ml of 4% surface modifying solution.

Weigh and take 100g of dried natural graphite and immerse in the surface modifying agent organic solution. Stir at 300rpm speed for 1 hour to form a thin layer of surface modifying membrane on the surface of the graphite granules. Then filter the graphite granules that are obtained.

Heat to dry. Sift with 300 mesh.

Put sifted graphite into sealed tubular high temperature furnace. Pass highly pure nitrogen at 10 liters/min of flow volume and increase the temperature at $15^\circ\text{C}/\text{min}$

to 400°C and hold the temperature for 1 hour.

Again increase the temperature at 10°C/min to 1000°C and hold the temperature for 3 hours. Then lower the temperature naturally to room temperature to obtain the improved graphite with surface modification.

- 5 Using D_{50} , the average granule diameter of said improved graphite granules is found to be 13.8 μ m, the crystallite interlayer spacing, d_{002} , is 0.3365nm, and its specific surface area is 2.8m²/g.

- Use said graphite as the active material as the negative electrode for the lithium ion rechargeable battery. Use LiCoO₂ as the active material for the positive electrode,
10 and LiPF₆ as the electrolyte salt. The solvent for the electrolyte solution is a mixture of the following organic solvent: ethylene carbonate, ethylene carbonate, and diethyl carbonate. The concentration is 1 mole per liter. The separator is polyethylene and polypropylene multiple separator.

[Embodiment 2]

- 15 In this embodiment, the surface modifying agent uses a 5% coal pitch in tetrahydrofuran solution. Other than this, all other processes are kept the same as Embodiment 1. The improved graphite obtained from this embodiment has fundamentally the same average granule diameter D_{50} and crystallite interlayer spacing, d_{002} , as Embodiment 1.

- 20 [Embodiment 3]

 In this embodiment, the surface modifying agent uses a 3% petroleum pitch and

chloroform solution. Other than this all other processes are kept the same as Embodiment 1. The improved graphite obtained from this embodiment has fundamentally the same average granule diameter D_{50} and crystallite interlayer spacing, d_{002} , as Embodiment 1.

5 [Embodiment 4]

This Embodiment uses a carbonization temperature of 800°C. Other than this, all other processes are kept the same as Embodiment 1. The improved graphite obtained from this embodiment has fundamentally the same average granule diameter D_{50} and crystallite interlayer spacing, d_{002} , as Embodiment 1.

10 [Embodiment 5]

This Embodiment uses a carbonization temperature of 1200°C. Other than this, all other processes are kept the same as Embodiment 1. The improved graphite obtained from this embodiment has fundamentally the same average granule diameter D_{50} and crystallite interlayer spacing, d_{002} , as Embodiment 1.

15 [Embodiment 6]

This Embodiment uses natural graphite with smaller average granule diameter as the starting material. Other than this, all other processes are kept the same as Embodiment 1. The improved graphite obtained from this Embodiment has an average granule diameter D_{50} of 8.2 μm and its crystallite interlayer spacing, d_{002} , is
20 fundamentally the same as Embodiment 1.

[Embodiment 7]

This Embodiment uses natural graphite with larger average granule diameter as the starting material. Other than this, all other processes are kept the same as Embodiment 1. The improved graphite obtained from this Embodiment has an average granule diameter D_{50} of $35.0\mu\text{m}$ and its crystallite interlayer spacing, d_{002} , is

5 fundamentally the same as Embodiment 1.

[Comparison Example 1]

Directly use the natural graphite material of Embodiment 1 as the active material for the negative electrode to make battery. Other than that, all other processes are the same as Embodiment 1.

10 [Comparison Example 2]

This Embodiment uses a carbonization temperature of 700°C , holding the temperature for 5 hours. Other than that, all other processes are the same as Embodiment 1.

Testing of the Characteristics

15 Specific Surface area: obtained using single-point BET method.

The conditions for heat analysis testing are as follows:

Instrument model and number: NETSCH STA 449C

Method: Differential Scanning Calorimetry and Thermal Gravimetric analysis,
that is, DSC-TG

20 Weight of Sample: Graphite 6.824mg

Crucible material: Al_2O_3

Furnace environment: air, flow speed is 25Nml/min

Process for increasing temperature: Starting from room temperature, increase temperature at 10°C/min to 1000°C.

The following operating characteristics of the batteries made from the

5 Embodiments and Comparison Examples are tested as follows:

For high current characteristics, $C_{3C}/C_{0.5C}$, the ratio of discharging capacity using 3C of current to discharge from 4.2V to 3.0V and from 0.5C of current from 4.2V to 3.0V.

For high current characteristics, $C_{2C}/C_{0.5C}$, the ratio of discharging capacity using
10 2C of current to discharge from 4.2V to 3.0V and from 0.5C of current from 4.2V to 3.0V.

Reversible specific capacity: (the discharge capacity of the initial discharge of from 0.1C of current from 4.2V to 3.0volts after it had been initially charged with 0.1C of current to 4.2V)/the weight of the active material of the negative electrode; and

15 Cycle life: A cycle is the process of using 1C of electricity to charge to 4.2V and then to discharge the electricity to 3.0V. For each cycle, the discharge capacity is the capacity of that cycle. In this invention, the cycle life is the number of cycles its takes for the discharge capacity of that cycle to reach 80% of the discharge capacity of the initial cycle.

20 The results of the testing of the above described battery characteristics for batteries made from Embodiments 1 though 7 and Comparison Examples 1 and 2 are

shown in the following table.

Number	Specific Surface Area m ² /g	High Current Characteristics		Reversible specific Capacity mAh/g	Cycle Life Span
		C _{3C} /C _{0.5C}	C _{2C} /C _{0.5C}		
Embodiment 1	1.8	86.2	96.4	340	280
Embodiment 2	2.8	86.1	96.9	351	312
Embodiment 3	2.6	82.6	96.4	338	264
Embodiment 4	3.5	80.5	95.8	330	320
Embodiment 5	2.3	88.4	96.7	350	277
Embodiment 6	4.2	82.8	95.1	332	320
Embodiment 7	1.5	80.2	94.6	340	245
Comparison Example 1	5.7	57.4	88.1	337	76
Comparison Example 2	4.8	72.2	94.5	332	253

The above table shows that the specific surface area of the improved graphite from Embodiments 1 to 7 is smaller than those of Comparison Examples 1 to 2. The batteries made from Embodiment 1 through 7 have excellent high current characteristics, higher reversible specific capacity and longer cycle life.

Figure 1 and Figure 2 are, respectively, the scanning electron micrograph of the

original graphite and improved graphite of Embodiment 1 using the equipment from JOEL Company with model number JSM-5160. The micrograph shows that the shape of the improved graphite is potato shaped or spherical shaped.

Figure 3 is the result of the heat analysis of the improved graphite from Embodiment 1. In that figure, the peak corresponding to 592.1°C is the amorphous carbon membrane. The peak corresponding to 821.2°C is the graphite core material. Under customary conditions, the peak corresponding to 500°C to 650°C should be the amorphous carbon membrane. The peak corresponding to 750°C to 850°C should be the graphite core material.

The improved graphite of this invention has excellent high current characteristics with great practical potential and superiority in many circumstance that require a high demand for rapid charging and discharges. Also, such active material for the negative electrode retains higher reversible specific capacity, and possesses longer cycle life, is stable and reliable and can satisfy the demands of practical applications. The fabrication method of this improved graphite of this invention has simple technology, is low cost, and easy for industrial production.

说明书附图

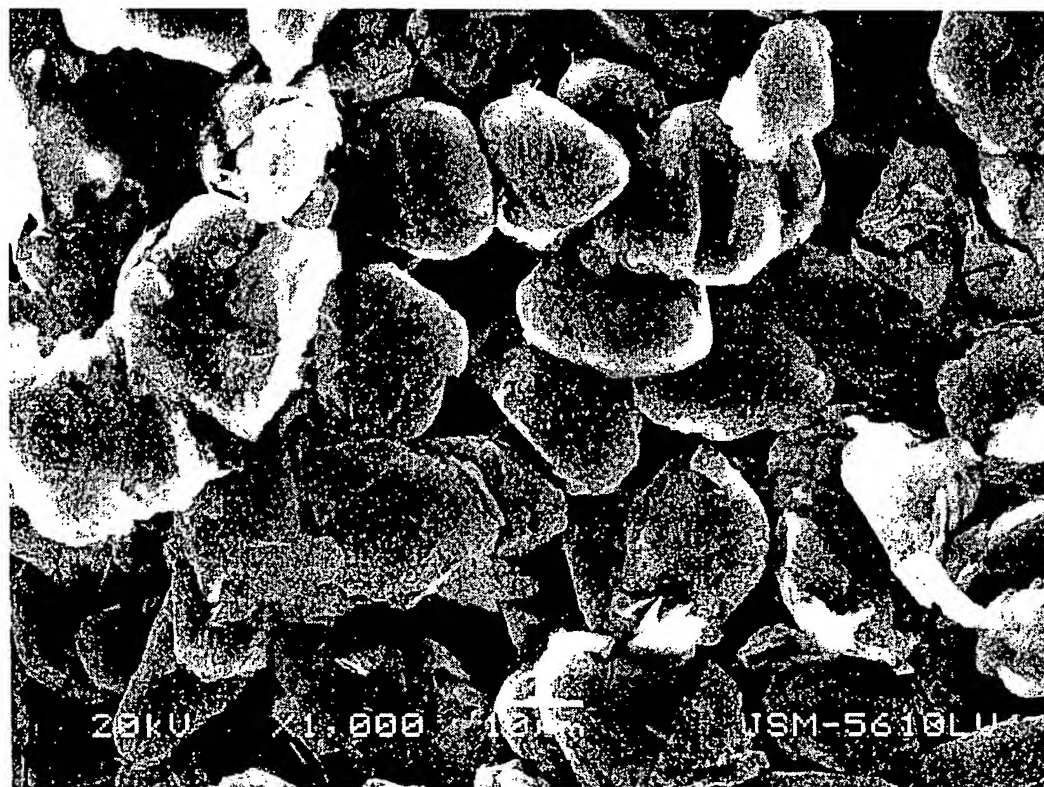


图 1

说明书附图

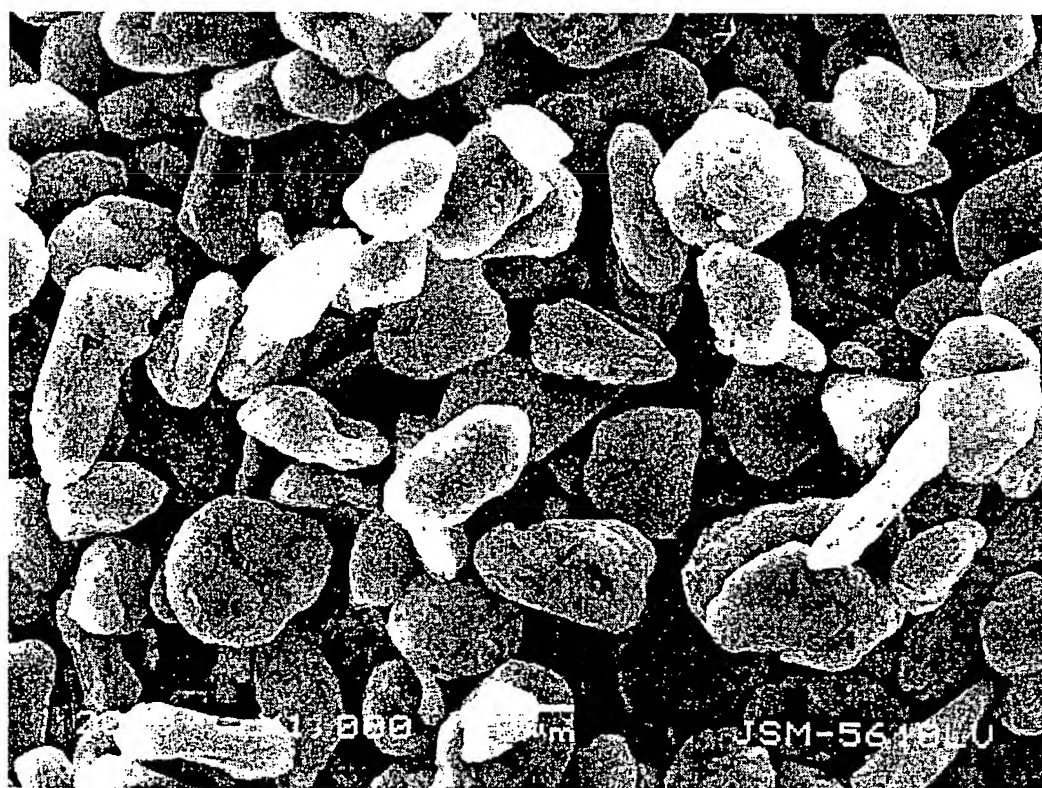


图 2

说明书附图

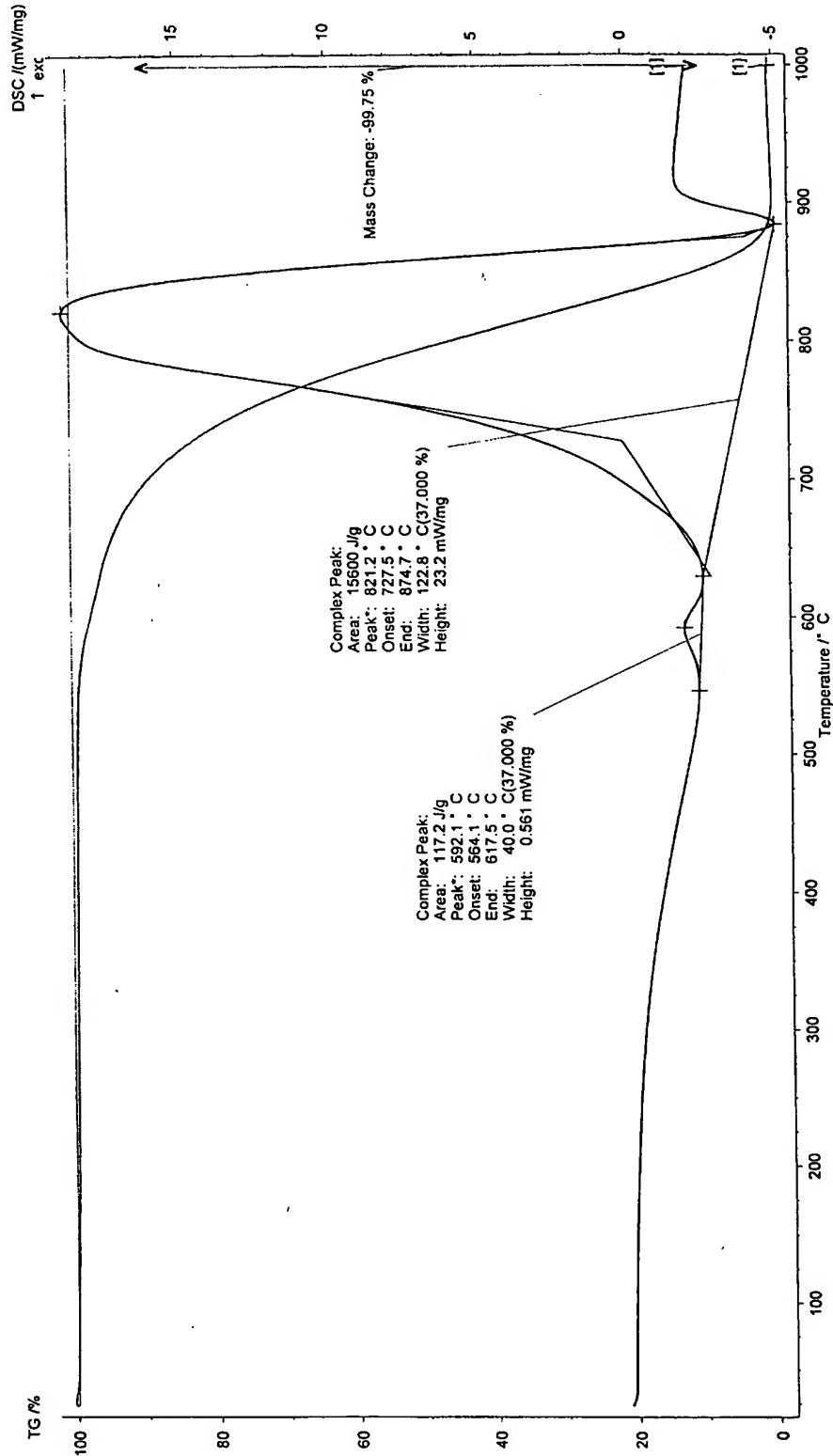


图 3